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OFFICE OF MANNED SPACE FLIGHT

APOLLO PROGRAM

MASS PROPERTIES STANDARD

JUNE 1, 1965

PREPARED BY

PERFORMANCE ANALYSIS AND CONTROL CONFIGURATION MANAGEMENT

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON, D.C. 20546

FOREWORD

This document updates M-DE 8000.006, Mass Properties Standard dated June 1, 1963, for all Apollo procurement after 1 June 1965. Those contractors using the original standard on "on-going" programs will not be affected.

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Director, Apollo Program Control

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1. SCOPE

1.1 This document establishes a system for the management of mass properties during procurement and use of space vehicles, or portions thereof. It is designed to permit the acquisition of systematized, verifiable and controllable mass properties of vehicle systems, to facilitate rapid establishment and reporting of inputs for the weight/performance relationship, and to enable parametric extrapolation from the reported systems to newly evolving systems.

author

1.2 The procuring activity shall, when necessary, specify all or part of this standard in contracts for portions of launch vehicles or spacecraft (such as engines, instrumentation, etc.) when such contracts are let directly by the procuring activity.

2. DEFINITIONS

2.1 Acquisition Phase. - The period in which full scale development (including testing) is accomplished. The Acquisition Phase ends when development and testing activity are no longer significant, and when updating changes are on contract.

2.2 Angles of Intersect. - The angles of intersection between the geometric axes and the principal axes of the item.

2.3 Contractor. - An individual or concern that enters into a direct contract with the procuring activity. (A division of a procuring activity may be its own contractor.)

2.4 Critical Mass Properties. - Any current mass properties which have mass properties limits.

2.5 Current Mass Properties. - The latest mass property data derived from design data, and including weight growth factors.

2.6 Definition Phase. - A formal period preceding full scale development (Acquisition Phase), during which preliminary engineering and contract management planning are accomplished.

2.7 Design Activity. - An agency having the responsibility for the design of the total vehicle or a portion thereof. A contractor, subcontractor or a division of a procuring activity may be a design activity.

2.8 Generation. - A component or group of components that forms a part of some larger or more complete functional group within a stage or module. The generation number refers to the number of digits assigned to a component or group of components under the functional code (Appendix B of this standard).

Example:	First Generation	10.	Instrumentation
	Second Generation	10.1	Sensors
	Third Generation	10.1.2	Pressure

2.9 Ignition Weight. - The total weight of a stage, module or combinations thereof, including propellants, fluids and items which vary in weight and location at the time of initiation of the ignition sequence.

2.10 Improvement Potentials. - Alternate configurations or design changes which, when incorporated into the basic design, will result in improved vehicle characteristics.

2.11 Item. - The vehicle, or portion thereof, such as a stage, module, engine, instrument unit, interstage, or contract end item.

2.12 Limiting Conditions. - Any system operating, handling, transfer, acceptance or other conditions to which any of the following apply:

a. Mass properties of the conditions have been established by contract as the allowable limits for satisfaction of performance incentive or other system objectives.

b. Mass properties of the conditions are decisively constrained by limiting values outside of which the mandatory system objectives or functions will not be achieved under the current design or operating characteristics.

c. Mass properties of the conditions exercise a decisive influence upon the acceptable system objectives or functions under the current design or operating characteristics.

2.13 Manufacturing Variation. - A random uncertainty resulting from the predicted or calculated effects of manufacturing processes. It may be treated as an uncertainty in dispersion studies.

2.14 Mass Properties. - The physical characteristics of weight, center of gravity, mass distributions, moments of inertia, products of inertia, and principal axes orientation under conditions being considered in this document.

2.15 Minimum Burnout Weight. - The weight at the end of effective action time for each stage where burning is to depletion of all main impulse propellants and fluids assumed to be available for expenditure.

2.16 Module. - An independent section of a spacecraft.

2.17 Outage. - The allowance for mean propellant-utilization system error.

2.18 Phase. - A period of time which denotes program progression.

2.19 Precision. - The degree of agreement of repeated independent measurements of a single quantity, yielded by repeated applications of a measurement process under specified conditions.

2.20 Procuring Activity. - Any agency which maintains administrative control of a contract entered into by the agency and design activity (contractor).

2.21 Random Error. - Error of a measurement method which fluctuates irregularly from observation to observation and which is caused by conditions that cannot be controlled completely.

2.22 Reference Datum. - A theoretical plane assumed to be exact for purposes of computation or reference, from which the location of vehicle features may be established.

2.23 Sliverage. - That portion of the solid propellant which is unburned at the end of action time.

2.24 Space Vehicle. - The entire vehicle assembly which is launched from the earth's surface.

2.25 Stage. - An independent section of a vehicle.

2.26 Subcontractor. - An individual or concern that enters into a contract with a contractor.

2.27 Target Weight. - Weights which are desirable program goals and which if met will provide a greater degree of mission flexibility.

2.28 Total Gross Weight. - The weight of the vehicle after loading is complete, and prior to ignition.

2.29 Uncertainty. - A general term for the estimated amount by which the observed or calculated value of a quantity may depart from the value accepted as true.

2.30 Vendor. - An individual or concern from which a procuring activity, contractor or subcontractor purchases equipment or services that usually do not require research and development effort.

2.31 Weight Contingency. - The nominal predicted weight allowance, for deficiencies in estimated or calculated weights, resulting from lack of detail in current design data. Weight contingency is a positive allowance which is historically justified and empirically determined. It is not treated as an uncertainty in dispersion studies, but may be subjected to uncertainty analysis when included as a part of a nominal Critical Mass Property being so analyzed.

2.32 Weight Growth. - The nominal predicted weight allowance for design changes, within the design activity's work statement responsibility, used to arrive at the reported launch conditions from current design data. Weight growth is an allowance which is historically justified and empirically determined. It is not treated as an uncertainty in dispersion studies, but may be subjected to uncertainty analyses when included as a part of a nominal Critical Mass Property being so analyzed.

3. REQUIREMENTS

3.1 General. - A system of mass properties control shall be established which is adequate to assure fulfillment of the program mass properties objectives. Qualified personnel shall be assigned the responsibility and authority to assure the establishment and maintenance of mass properties objectives, and the effective planning and execution of mass properties control functions, in accordance with the requirements of this document. The design activity shall be prepared to review with the procuring activity all submitted plans covering his technical and organizational approach to mass properties control problems.

3.2 Mass Properties Objectives

3.2.1 Development of Objectives for the Acquisition Phase. - The primary purpose of all mass properties effort in the Conceptual and Definition Phases shall be to develop achievable mass properties objectives to be included in the System Specification for an Acquisition Phase. During the initial development of, or any subsequent change to, mass properties objectives, the design activity shall give particular attention to required substantiating analyses, in order to assist the procuring activity in specifying the objectives and their limitations.

3.2.2 Specified Mass Properties Base for Control and Reporting

3.2.2.1 System Specification Mass Properties Base. - Unless otherwise directed by the procuring activity, mass properties objectives included in an approved System Specification shall constitute the Specified Mass Properties Base for control and reporting purposes at go-ahead for any phase. If an approved System Specification is not available at the time of go-ahead, mass properties which are jointly coordinated and documented shall be treated as the Specified Mass Properties Base for control and reporting purposes, until a System Specification is approved.

3.2.2.2 Target Mass Properties Base. - When directed by the procuring activity, Target Mass Properties shall be established and supported by substantiating analyses in lieu of System Specification Mass Properties. Such Target Mass Properties shall constitute the Specified Mass Properties Base for control and reporting purposes for added assurance that System Specification mass properties objectives are met or bettered.

3.3 Control

3.3.1 Planning. - Fulfillment of program objectives requires the procuring activity to have cognizance of the design activity's organizational and technical approaches to the mass properties control essentials of analysis, verification, improvement, reporting, and operational support in the field. The design activity shall prepare plans for such approaches in accordance with this document.

3.3.2 Determination of Mass Properties Condition

3.3.2.1 Design Monitoring. - The vehicle design including the operating characteristics of fluid transfer, loading, and utilization systems shall be analyzed and monitored continuously to establish current mass properties, and their trend relationships with the Specified Mass Properties Base.

3.3.2.2 Design Sign Off. - All engineering drawings, procurement specifications, shop deviations, and other sources of change to components shall be signed, prior to release for manufacturing, by personnel responsible for the design activity's mass properties control effort. The signature shall verify that the mass properties of the components are correctly obtained, coded, and identified in the mass properties accounting system.

3.3.2.3 Uncertainty Analyses. - Analyses shall be conducted to ascertain the uncertainties of all Critical Mass Properties to provide values for use in dispersion studies, to verify computed nominal values analytically, and to assist in identifying elements which warrant test verification.

3.3.2.4 Limiting Condition Analyses. - Analyses shall be conducted for the purpose of assisting the procuring activity in establishing and maintaining the contractual mass properties limits, and to establish other mass properties limits based on mandatory and acceptable system objectives and functions, under the current design and operating characteristics.

3.3.2.5 Verification of Critical Mass Properties. - Each Critical Mass Property and its conformance to limits shall be verified by the design activity. Verification is to be performed by approved analytical or experimental methods, or by a combination thereof. The methods may be applied to the total Critical Mass Property or to each sub-element. Typical parameters requiring verification by analysis, or by acceptance, development, or other special tests, are:

a. Calibrations of propellant and fluid system capacities for the anticipated environments.

b. Weight, balance, inertia, and principal axes.

c. Propellant and fluid density characteristics for the anticipated environments.

d. Levels achieved in loading, or use, of propellants and liquids.

e. Loaded or terminal weights of propellants, gases, and liquids for the anticipated environments.

f. Losses sustained during thrust build-up, hold-down, thrust decay, vent or drain overboard, boil-off retained.

g. Residuals for the anticipated environments.

h. Actual environmental conditions.

3.3.2.6 Detail Part and Component Measurements. - Measurement programs for the determination of the actual weight of parts and components shall be established. The measured data shall be used to verify and replace the calculated data in mass properties reports as the fabrication cycle progresses.

3.3.2.7 Contract End Item Measurement. - At the time of test measurements of contract end items, or major portions thereof, the item being measured shall simulate the flight condition as closely as possible. In the case of dry mass property measurements, the item shall be in a dry condition insofar as it is practical and shall be at least 95 percent complete by weight in this condition, excluding hazardous items (squibs, explosive devices, etc.) as applicable, and design components (fins, stubs, etc.) not normally installed at the location where the measurement is made. The manufacturing status of the item shall be documented at the time of measurement. A log shall be initiated at the time of measurement, in accordance with paragraph 3.4.3.9. If design components are missing at the time of measurement, and actual mass properties of these components shall be obtained and entered in the log at the time such components are installed on the item. In the case of test operations involving the handling, transfer and loading of fluids and propellants into the vehicle, adequate instrumentation, procedures, and data shall be provided to measure the quantities required to establish the weight actually loaded.

3.3.2.8 Notification of Measurement. - In all cases of measurements to be performed in accordance with procuring activity approved procedures, the design activity shall notify the procuring activity of the time and place at least one week in advance.

3.3.2.9 Post-Flight Analyses. - Adequate instrumentation and procedures, subject to approval by the procuring activity, shall be provided to permit post-flight analyses of the actual initial and terminal mass property conditions of the flight. Post-flight analyses shall be performed to relate the planned conditions with those of the flight, and to relate the performance achieved to these conditions.

3.3.2.10 Field Support of Flight Operations. - The design activity shall plan and provide adequate mass properties support, subject to approval by the procuring activity, to flight operations in the field. This support shall maintain Critical Mass Property inputs to flight planning which are in agreement with the actual vehicle configuration, and with conditions affecting the planned loading and utilization of fluids and propellants.

3.3.3 Improvement Action

3.3.3.1 Means to Meet Specified Mass Properties. - Mass properties control personnel, working with analytical and design personnel, and considering such governing criteria as reliability, performance, schedule, and cost, shall determine means to insure that specified mass properties are met or bettered.

3.3.3.2 Improvement Potentials. - A summary of all improvement potentials which could be used to offset mass properties or performance degradation shall be maintained and reported. Mass properties analyses for all alternative design configurations shall be included in the documentation.

3.3.3.3 Problem Definition. - The procuring activity shall be notified immediately of any problem requiring improvement action, with a statement of the problem and the potential effect of mass properties and performance when:

a. Program objectives are endangered.

b. Established control parameters have been reached or exceeded.

3.3.3.4 Corrective Action. - The design activity shall take, or recommend to the procuring activity, actions which will correct the recognized deficiencies.

3.4 Documentation. - Reports shall be submitted in accordance with this document, unless otherwise specified by the procuring activity.

3.4.1 Types of Reports Required. - The required reports are described by the following general types. Their specific composition is set forth in Section 3.4.2 and may vary according to the phase of procurement.

3.4.1.1 Detail Mass Properties Reports. - Reports in this category provide comprehensive detail reference documentation of the mass properties as they exist at initial, intermediate and final stages of procurement. Submittals occur at specified times in Funded Study, Definition, and Acquisition phases. Vehicles or vehicle blocks reported upon shall be those specified by the procuring activity.

3.4.1.2 Mass Properties Status Reports. - Reports in this category provide a current status of the mass properties, of changes since the last report, and of problems encountered and progress made in tasks associated with the mass properties control program. Submittals occur at specified intervals during extended Funded Study, Definition, and Acquisition phases. Submittals also occur at specified events during flight preparation and launch of each vehicle. Vehicles or vehicle blocks reported upon shall be those specified by the procuring activity.

3.4.1.3 Procedural Reports. - Reports in this category provide outlines of the design activity approach for satisfying the requirements of this document. Initial submittals occur sufficiently in advance of implementation to permit their review and approval.

3.4.1.4 Miscellaneous Reports. - Submittal dates for the following reports in this category cannot be specified in this document.

3.4.1.4.1 Contract Change Proposals. - Information to evaluate and substantiate the effect on vehicle mass properties from proposed changes. Submittal occurs with the Change Proposal.

3.4.1.4.2 Test Results. - Results of testing to verify parameters for the mass properties of fluids or propellants submitted in accordance with the design activity's Mass Properties Verification Plan.

3.4.2 Report Composition

3.4.2.1 General. - This section establishes the minimum content requirements for the various reports called for under the submittal schedule set forth in Section 3.4.4.

3.4.2.1.1 Unit System of Measure. - Data contained in the required mass properties reports shall be in the unit system specified by the procuring activity.

3.4.2.1.2 Forms. - Report elements which require the use of forms shall employ forms similar to those illustrated in Appendix A.

3.4.2.1.3 Coding. - To provide a uniform basis for mass properties comparison and to facilitate the preparation of mass properties summaries, the design activity shall employ the functional code and nomenclature in accordance with Appendix B, and the definitions in accordance with paragraph 6.3. Where contract responsibility includes items comprising more than one stage, the components for each stage shall be tabulated separately in each report.

3.4.2.1.4 Current Mass Property Relationships. - The design activity shall report current mass properties summaries and details in a manner to facilitate rapid establishment of their relationship to current performance, design, and mission functions of the system.

3.4.2.1.5 Parametric Mass Property Relationships. - The design activity shall include, in Detail Mass Properties Reports, sufficient details of the associated design and mission criteria to enable use of the reports for parametric extrapolations to trustworthy mass property, performance, design, and mission function relationships in new systems which may be evolved from the reported system.

3.4.2.2 Report Elements. - Reports shall be composed of the applicable elements listed in Table 1, page 20, and described in Section 3.4.3.

3.4.3 Description of Report Elements

3.4.3.1 Title Page. - The first page of each report shall be a title page containing the following information, as applicable:

a. Report number

b. Type of submittal

c. Vehicle flight number

d. Stage or module

e. Applicable serial numbers

f. Date of issuance

g. Actual date of data reported

h. Design activity's name

i. Mission identification

3.4.3.2 Table of Contents. - A table of contents shall follow the title page.

3.4.3.3 Introduction. - Summarize significant material contained in the report. References to substantiating documents, reports, correspondence, and other pertinent information shall be included.

Note: For reports containing a Mass Properties Summary, a concise management review tabulation shall be included, presenting the following, as applicable:

a. Weights - revised Specified Weight Base, last current status, and current status together with the change from last to current for:

1. Total dry weight

2. Residuals and reserves

3. Dry weight items jettisoned and ablated during flight

4. Subtotal of (1) and (2) less (3) (minimum burn-out weight)

5. Total available design thrust propellants

6. Ignition weight

7. Maximum loadable tank capacity (main propellants)

b. Control Parameter Encroachment - for each current mass property which has reached or exceeded its control parameter, specify the following:

1. Control parameter and its associated limit.

2. Current nominal mass property value.

3. Accuracy or uncertainty of the current nominal value.

c. Highlights of newly encountered problems.

3.4.3.4 Design Activity Mass Properties Organization. - Furnish organization charts and descriptive material to identify the key personnel responsible for mass properties control, their responsibilities, their relationship to other elements of the organization, and the percentage of their time devoted to the contract. This data, submitted for information only, will be for procuring activity internal use.

3.4.3.5 Mass Properties Summary. - Provide first and second generation data derived from current detail data. To provide a logical buildup to total gross weight, the items comprising the dry configuration shall be listed and totaled, the residuals added and a total established. At this point, for reference purposes only, the total of dry weight jettison and ablation items shall be entered and subtracted and a total established for the minimum burn-out condition. The remaining items shall then be listed and added to establish the

condition at lift-off, ground ignition, and total gross weight. This information shall be reported on a form similar to Form 1, Part I (Appendix A) for items (a) thru (i) and (l) below, and on a form similar to Form 1, Part II (Appendix A) for items (a), (b), (f), (j), and (k) below. The minimum acceptable amount of information reported shall be as follows:

a. Code - first and second generation functional code, except for propulsion systems which shall be carried to at least the third generation.

b. Description - functional code and weight summary titles.

c. Specified Weight Base - original specified weight base.

d. Procuring Activity and Government Furnished Equipment (GFE) Changes - changes in weights resulting from design changes initiated by the procuring activity and over or under weight of GFE.

e. Revised Specified Weight Base - the algebraic sum of (c) and (d) above.

f. Current Weight.

g. Changes, Last to Current - change in current weight since last report. These changes shall be cross-referenced to the change analysis element of the report (par. 3.4.3.7.1).

h. Percentage Breakdown of Current Weight - percent of current weight which is estimated, calculated, and actual.

i. Note Number - reference numbers for explanatory notes, remarks, or change analysis reference.

j. Center of Gravity - center of gravity determined from the reference datum.

k. Moment of Inertia - current moments of inertia.

l. The last line entries on Form 1 shall recapitulate items (c) through (h) for the total weight included for the GFE and design activity responsibility.

3.4.3.6 Detail Mass Properties. - Provide a complete breakdown of the item's current mass properties. This data shall be prepared on a form similar to Form 2, Parts I and II (Appendix A), and shall include, but is not limited to, the following:

a. Code - applicable first, second, and third generation functional code, except for propulsion systems which shall be carried to at least the fourth generation.

b. Description - applicable functional code and summary titles.

c. Class - third generation weight as estimated, calculated, or actual.

d. Current Mass Properties.

3.4.3.7 Change Analysis and Improvement Potentials

3.4.3.7.1 Mass Properties Change Analysis. - An explanation of significant changes in

current mass properties data and of all changes in the Specified Weight Base shall be reported on a form similar to Form 3, Parts I and II (Appendix A). All changes in Government Furnished Equipment shall be identified and explained. Each change shall be cross-referenced to the Mass Properties Summary report element (par. 3.4.3.5) and the Sequenced Mass Properties Data element (par. 3.4.3.10) as applicable. The minimum acceptable amount of information shown in this element shall be as follows:

a. Note Number - reference number corresponding to the note number in the Mass Properties Summary element or the Sequenced Mass Properties Data element.

b. Code - all functional code numbers affected.

c. Change, Total - total change in mass properties for each functional code.

d. Effective Point - vehicle effectivity point, as applicable.

e. Change, Design Activity Responsibility - change in mass properties as a result of design activity changes.

f. Change, Procuring Activity Responsibility - change in mass properties resulting from changes requested by the procuring activity. In addition, where the current change differs materially from the authorized change, appropriate comment shall be included, calling attention to and indicating the magnitude of the differences in the mass properties.

g. Remarks - explanation of each change, with referenced authority. Changes which result from reconciliation of predicted values with actual measurement of contract end items, or major portions thereof, shall be fully identified.

3.4.3.7.2 Pending Mass Properties Change Analysis. - Each pending change in mass properties of any significance, including contract change proposals, shall be reported on a form similar to Form 3, Parts I and II (Appendix A). Separate forms will be used to itemize the following categories of change:

a. Changes established subsequent to the basic report close-out date.

b. Corrective action changes recommended by the design activity to correct recognized deficiencies.

c. Other pending changes.

Contained in this report element shall be the following minimum information for each change:

1. Change Identification - case number assigned by the design activity or the procuring activity.

2. Code - all applicable first and second generation functional code numbers affected.

3. Change - current and pending mass properties for each affected code and total mass properties change.

4. Effective Point - vehicle number or approximate date when pending change will be incorporated.

5. Remarks - explanation of each change, including reference correspondence, change order number, drawing number, and other pertinent data.

3.4.3.7.3 Summary of Improvement Potentials. - Tabulate all mass property improvement potentials which could be used to offset degradations. Include identification or case number, and best estimates of effects on mass properties, schedules, costs, reliability and effectivity. It shall indicate whether technical feasibility is established or requires further study. Items which have been rejected shall be accumulated, together with the reasons for rejection.

3.4.3.8 Unresolved Problems. - All problems that may affect mass properties shall be reported at the earliest possible time, including the system affected, action being taken and an estimate of when the problem will be resolved.

3.4.3.9 Mass Properties History Log. - A history log similar to Form 4, Part I and Part II (Appendix A), for each item shall be initiated at the time of the first major measurement and maintained until launch. Each sheet of the log shall be numbered and shall identify the time as indicated on the form. The first entry shall be the "as measured condition" mass properties and shall include the identification of the Actual Mass Properties Data Record from which the data was extracted (3.4.3.18). A copy of the Shortage List contained in the variance items (3.4.3.18.2c) shall remain with each copy of the history log, such that dry weight of the item may be developed at any time by summarizing the log and adding the mass properties of equipment not installed. Subsequent mass properties entries shall be made each time an item is added, removed, or relocated, and corresponding adjustments made in the shortage list, as applicable. Calculated data may be used for the center of gravity location and the inertias if the procuring activity has not established measurement requirements. These entries shall be in chronological order and shall include:

a. Entry Number - chronological number of the entry.

b. Date/Time - date and time of entry.

c. Signature - signature of authorized individual responsible for entry.

d. Description - name, drawing number, serial number and functional code.

e. Physical Change - addition, removal, or relocation shall be indicated by the use of plus (+) or minus (-).

f. Mass Properties.

The history log and shortage list shall be maintained in a current state at all times, and one copy each shall remain with the item. Duplicate copies, including the summary, shall be available to the procuring activity upon request. The history log and its final summary shall be delivered and in the hands of the procuring activity within 24 hours after launch.

3.4.3.10 Sequenced Mass Properties Data. - This report element shall contain weight, balance, and inertia data on the stage/vehicle for each major event of the mission, and shall be reported on a form similar to Form 5 (Appendix A). The design activity shall use current detail data and engineering information to develop mass properties for each mission event. These data shall start with the stage/vehicle at ground ignition and continue throughout the mission to separation, impact and recovery, as applicable. The weights and code numbers of items subtracted from the weight totals in getting from one event to

another shall be shown. The information reported in this section shall be the following, as applicable:

a. Code - functional code number.

b. Description - functional code title or mission event.

c. Weight - current weight. Significant changes since the previous report shall be underlined and cross-referenced to the change analysis element (par. 3.4.3.7).

d. Center of Gravity - center of gravity location measured from the reference datum. Significant changes since the previous report shall be underlined and cross-referenced to the change analysis element.

e. Moment of Inertia - current moment of inertia. Significant changes since the previous report shall be underlined and cross-referenced to the change analysis element.

f. Product of Inertia - where required, columns may be added to present products of inertia.

g. Angles of Intersect - where required, between the principal and geometric axes.

3.4.3.11 Powered Flight Mass Properties. - This report element shall contain mass properties data used to derive performance information. It shall include, but not be limited, to the following:

a. Tabulation or plot of weight, center of gravity, pitch, yaw, and roll moments of inertia versus mission time.

b. Assumptions made and data used to derive these mass properties (propellant weights, propellant duration, liquid inertias during flight, engine parameters, ejection time on all items, stage burning time).

c. Reference shall be made as applicable to other report elements from which the above data may be extracted or based upon.

3.4.3.12 Diagrams. - Include sketches, curves, and drawings (elevation and plan) sufficient to supply the following minimum information:

a. Principal structural stations and structural interface locations.

b. Reference datum for the 3-axes moment arms, showing quadrant numbers and gimbal plane stations.

c. Significant lengths, heights, widths, and diameters.

d. Sections of the vehicle as sectionalized for shipping and handling.

e. Locations of jig, leveling, and weighing points.

f. Thrust reaction stations, giving direction of thrust and points of application. Where the thrust direction is not fixed, the maximum angle of variation shall be specified.

g. Center of gravity envelope for stages and the complete vehicle, as applicable.

h. Graphs, beginning at the proposal stage, presenting the historical record for dry weight, minimum burn-out weight, launch weight, and design activity and procuring activity weight changes, as a function of time.

3.4.3.13 Mass Properties Substantiating Data. - Validate the reported values by including the analytical, statistical, or empirical methods used in their derivations. When the complexity of the equations and computer programs prevents inclusion in the document, a summary shall be presented, and the detail methods shall be readily available for review by the procuring activity. Where values are determined by an accumulation of separate equipment groups, values shall be given for each component.

3.4.3.14 Government Furnished Equipment. - A separate tabulation of all GFE shall be prepared for each vehicle stage or module of each flight number, showing the drawing number and description, serial number where applicable, number required, and the unit and total dry and total wet specified mass properties. Provisions shall be included to record the actual unit and total weight and the difference between total specified and total actual weight.

3.4.3.15 Computer Cards or Tapes. - These are detail mass properties to be prepared in accordance with the procuring activity's instructions.

3.4.3.16 Mass Distribution. - Data shall be prepared for all critical conditions which depend on mass distribution for their analyses and shall be in tabular or graphical form presenting the following information, including supporting calculations:

a. Weight per unit of longitudinal length representing distributed loads.

b. Concentrated loads and related reaction points.

c. Cantilevered loads and related reaction points, moments, and moment direction (plus or minus).

3.4.3.17 Design Data for Mass Properties Analysis

3.4.3.17.1 Mass Properties Dependent Design Information. - These data include major dimensional factors and design criteria used in the development of mass properties estimating techniques and comparative studies. Appendix C presents a list which shall be used as a guide for data submitted.

3.4.3.17.2 Structure for Design Features. - Net structure for special functions, installations, and other design features considered to be other than basic on any major design group shall be included. Insofar as practicable, the amount buried or masked in "basic structure" and quantitatively evaluated by some rational procedure should be listed for such items as body joints, major cutouts, removable structural panels, etc. Values shall be accompanied by amplifying and clarifying remarks or data verifying the means of determination.

3.4.3.18 Actual Mass Properties Data Records. - Actual mass properties data records shall be provided for each major measurement performed in accordance with procedures approved by the procuring activity.

3.4.3.18.1 Records for all Measurements. - These records shall include the following for all such measurements:

a. Location where measurements were performed, signature of authorized individual responsible for the entries, date and time of entries, date of last equipment calibration, document number of the approved measuring procedures, and identification of the item measured.

b. Provision for the signature of a procuring activity witness on each page of the data record that includes measured data.

3.4.3.18.2 Records for Dry Mass Properties Measurements. - Records for dry mass properties measurements shall include:

a. Tables showing the applicable scale readings; tare; net weight; moment arm; moment for longitudinal, vertical, and lateral center of gravity; and calculations showing the derivation of the "as measured" weight and center of gravity condition from the measurements.

b. Measurements taken for the determination of moment and product of inertia, and calculations showing the derivation of the "as measured" inertias from the measurements.

c. Variance Items - A list of items, including a Shortage List, for the weight, center of gravity, and inertia data to be added to or subtracted from the "as measured" condition to obtain the actual "dry weight" determination for launch condition.

d. Diagrams of measuring equipment and related fixtures showing pertinent dimensions and other data required for the determination of the "as measured" weight, center of gravity, and moment and product of inertia.

3.4.3.18.3 Records for Fluid Mass Properties Measurements. - A guide for presenting the required data is shown in Appendix E 20.0 g.

3.4.3.19 Summary of Critical Mass Properties. - Provide a table stating the relationship between the current and allowable values for all of the Critical Mass Properties for each mission, including at least the following:

a. Limiting mass property value.

b. Current mass property value.

c. Accuracy or uncertainty of the current value.

d. Existing tolerance on the current value.

e. Reference to the current Critical Mass Property Uncertainties analysis, and to the current Mass Properties Limits analysis.

3.4.3.20 Evaluation of Flight. - Compare the actual launch mass properties, and the actual mass properties variations throughout the flight, with the predicted mass properties flight data. In liquid propellant systems, the evaluation shall include analytical extrapolation, from the actual propellants at thrust termination, to the outage condition which would have existed had burning been to depletion. An evaluation of the critical mass properties,

uncertainties, and other pertinent data shall be included in the final post flight reports to substantiate mass properties contained in the design activity's Final Flight Evaluation Report. Quick Look reports should be confined to gross information and analysis based on the best available sources to confirm either normal flight mass properties conditions or apparent anomalies.

3.4.3.21 Critical Mass Properties Uncertainties.- Provide sufficient data for, and analysis of, the random critical mass property uncertainties to be used in association with studies of trajectory dispersions and other limiting conditions. The information is to be organized to permit determination of those sources of error which are large enough to warrant test verification of nominals and uncertainties and to serve as a guide in the approach to any testing required. This analysis shall include at least the following for each mission:

a. Uncertainties in the critical mass property conditions of the system shall be summarized and substantiated by detailed analysis of each contributing error source. Each quantity for which uncertainties are summarized shall be broken down to a level corresponding with its principal elements.

b. Analysis or discussion to describe the derivation of each measured, calculated, or otherwise assigned uncertainty, along with the nominal value assumed for the analysis. When included in the nominals being subjected to analyses, weight growth and contingency allowances shall be identified.

c. Error sources selected shall be described, and shall include uncertainties anticipated or indicated by analysis of the following, as applicable:

(1) Nominal inert and fluid weights, together with the launch procedures, ambient conditions, in-flight changes, and manufacturing variations affecting same.

(2) Instrumentation performance associated with verification or testing of the above.

3.4.3.22 Mass Properties Limits.- Mass Properties Limits shall include the following:

a. A tabulation of the limiting conditions and the associated mass properties limits which are established by contract. Include reference to the contract document and page where the requirement is placed.

b. A tabulation of the limiting conditions and the associated mass properties limits which are established by mandatory and acceptable system objectives and functions under the current design and operating characteristics.

c. Analyses supporting and establishing the allowable limiting values of each mass property condition tabulated in (b) above.

3.4.3.23 Parameters and Inventory of Fluids and Propellants Loaded.- Present the fluid and propellant load parameters which are required to establish the loads. A guide for presenting the required data is shown in Appendix D.

3.4.3.24 Capacity and Loading Information for Fluids and Propellants.- Provide the nominal data required to determine the parameters and procedures for pre- and post-flight

evaluation of the loaded and unexpended fluid and propellant mass properties. A guide for presenting the required information is shown in Appendix F.

3.4.3.25 Mass Properties Verification Plan.- Identify Critical Mass Properties, or elements thereof, for which experimental verification is proposed, and those for which experimental verification is not proposed. Justification shall be provided for both cases. Test plans shall be included for experimental measurements proposed. A guide for preparing the required information is given in Appendix E.

3.4.4 Report Submittal Requirements

3.4.4.1 Schedule of Submittals.- Unless otherwise specified by the procuring activity, Table I constitutes the required submittal schedules for reports. The schedules reflect required dates for receipt of final design activity approved documents at the office of the procuring activity where technical management of the program resides. Where the interests of the program require, the design activity shall be prepared to provide supplemental data or informal inputs for any report in an expeditious manner.

3.4.4.2 Distribution.- Direct distribution is required to the organization which has technical mass property cognizance of the program, and to such other distribution as the procuring activity specifies.

3.4.4.3 Approvals.- Unless otherwise specified by this document, or the procuring activity, all reports are submitted for information only.

3.5 Subcontractor Surveillance.- The design activity shall be responsible for the adequacy of the mass properties control efforts of the subcontractors for their respective system. Where applicable, a mass properties section, comparable to and compatible with the requirements set forth in this document, shall be prepared and incorporated into each procurement specification.

3.6 Associate Design Activity and GFE Suppliers Interfaces.- Associate design activity and GFE suppliers shall be responsible for assuring that there is sufficient interchange of mass properties data to support the integration of subunit mass properties into the complete unit mass properties and shall promptly respond to requests from their interfaces and integration design activities for information required by them in satisfaction of the requirements of this document.

3.7 Coordinate Axes.- To provide a common reference basis for all mass properties, performance, and design data, the coordinate axes and notation system shown in Figure 1 shall be used. The X axis shall always be the thrust axis of the vehicle when on the launch pad. Insofar as it is practical, all spacecraft shall use coordinate axes consistent with their position on the launch vehicle on the pad. The vertical and lateral reference datums shall be the planes defined by the intersection of the X-Y axes and the X-Z axes, respectively. The longitudinal reference datum for the total space vehicle shall be established by the procuring activity.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection.- Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may utilize his own facilities or any commercial laboratory acceptable to the Government. The Government reserves

the right to perform any of the inspections set forth in the standard where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Inspection Methods

4.2.1 Examination.- The mass property control data shall be thoroughly examined to determine conformance with this standard with respect to all the requirements noted herein.

4.2.2 Delivery.- The data package shall be examined to ascertain that the preparation for delivery conforms to this standard.

5. PREPARATION FOR DELIVERY

5.1 Preservation and Packaging

5.1.1 Level A.- The mass properties control data shall be preserved and packaged in accordance with Method IC of Specification MIL-P-116.

5.1.2 Level C.- Preservation and packaging shall be as stipulated in paragraph 5.1.1.

5.2 Packing

5.2.1 Level A.- Mass properties control data shall adequately be packed to meet the carriers' rules and regulations and to insure safe delivery at destination. Such packs shall meet security regulations when contents are classified. See paragraph 6.2.2.

6. NOTES

6.1 Intended Use.- The procuring activity's mass properties personnel will be continuously evaluating each design activity's mass properties control capability and effectiveness. The results of the evaluation will be summarized and documented, within the procuring activity, as frequently as conditions (overweight, incomplete reports, late submittals, etc.) warrant; however, each design activity will be completely evaluated within six months after being awarded a contract. These reports will be for Government internal use only and will not be provided for contractor information. The evaluation will be based upon, but not limited to, the following:

a. Trend relationship between design activity mass properties summaries and specified mass properties requirements.

b. Completeness of data submitted.

c. Compatibility of measured data with estimated and calculated data.

d. Compliance with data submittal schedules.

6.2 Information for Contracting Officer

6.2.1 Procurement Document.- Procurement documents should specify the following:

a. Title, number, and date of this standard.

b. Selection of applicable levels of preservation, packaging, and packing required.

c. Items of data required (see paragraph 6.3).

d. Additional Quality Assurance provision as applicable.

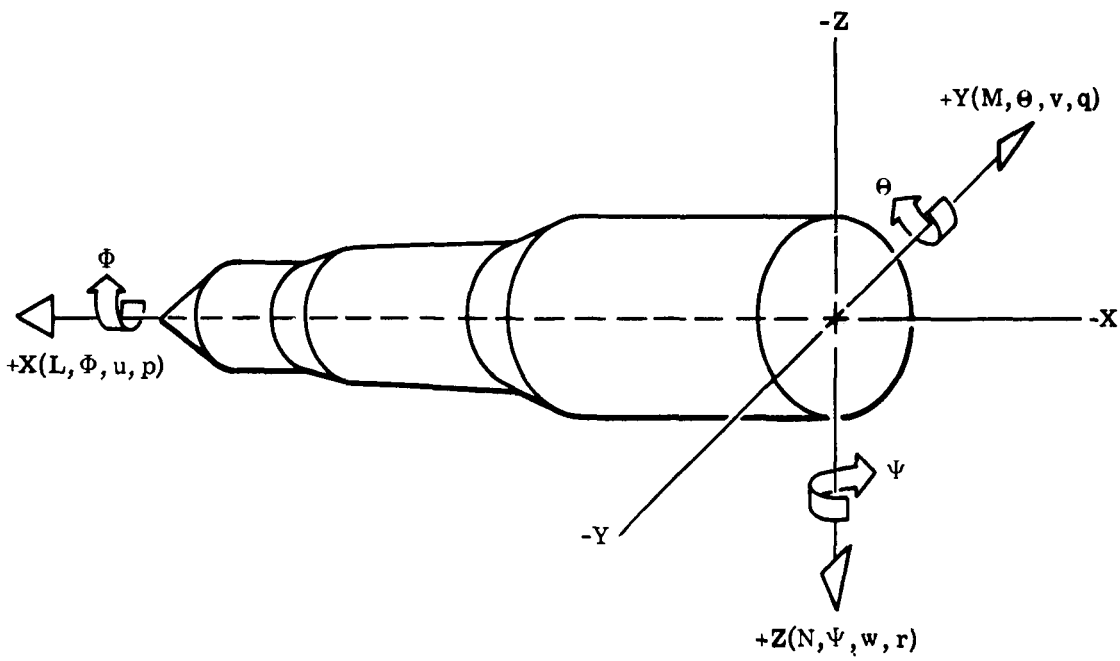
6.2.2 Classified Data.- The applicable security regulations of the procuring activity shall control the processing and distribution of classified data.

Custodians:

NASA - MAP

Preparing activity:

Review/user information is current as of the data of this document.



DIRECTION	AXIS SYMBOL	MOMENT SYMBOL	POSITIVE ROTATION	ANGLE	ANGLE SYMBOL	LINEAR VELOCITY	ANGULAR VELOCITY
LONGITUDINAL	X	L	Y TO Z	ROLL	Φ	u	p
LATERAL	Y	M	Z TO X	PITCH	Θ	v	q
VERTICAL	Z	N	X TO Y	YAW	Ψ	w	r

THE RIGHT-HAND RULE IS THE BASIS FOR THE SPACE VEHICLE SIGN CONVENTION

Figure 1. Vehicle Coordinate Axes and Notation System

Program Phase	Funded Studies (any phase)	
Report Type	Detail	Statu
Column No.	1	2
Schedule of Submittals	Semiannually for studies of 1 year or more; at completion of all studies	Every other week for studies of 2 months or less; at first of each month for studies of more than 2 months

Report Element	Tasks (para)	Tasks Page	Report Elements (para)	Report Elements Page		
Title Page			3.4.3.1	7	x	x
Table of Contents			3.4.3.2	8	x	x
Introduction			3.4.3.3	8	x	x
Contractor Mass Properties Organization	3.1	3	3.4.3.4	8		
Mass Properties Summary	3.4.2.1.4	7	3.4.3.5	8	x	x
Detail Mass Properties	3.4.2.1.4	7	3.4.3.6	9	x	
Mass Properties Change Analysis	3.3.2.1, 3.3.2.2	4	3.4.3.7.1	9	x	x
Pending Mass Properties Change Analysis	3.3.2.1, 3.3.2.2, 3.3.3.4	4 6	3.4.3.7.2	10		x
Summary of Improvement Potentials	3.3.3.1, 3.3.3.2	6	3.4.3.7.3	10		x
Unresolved Problems	3.3.3.3	6	3.4.3.8	11		x
Mass Properties History Log	3.3.2.7	5	3.4.3.9	11		
Sequenced Mass Properties Data	3.4.2.1.4	7	3.4.3.10	11	x	x
Powered Flight Mass Properties	3.4.2.1.4	7	3.4.3.11	12	x	
Diagrams	3.4.2.1.4	7	3.4.3.12	12	x	x
Mass Properties Substantiating Plan	3.2.1	3	3.4.3.13	13	x	
Government Furnished Equipment	3.4.2.1.5	7	3.4.3.14	13	x	
Computer Cards or Tapes	3.4.2.1.4	7	3.4.3.15	13		
Mass Distribution	3.4.2.1.4	7	3.4.3.16	13	x	
Mass Properties Dependent Design Information	3.4.2.1.5	7	3.4.3.17.1	13	x	
Structural Increments for Design Features	3.4.2.1.5	7	3.4.3.17.2	13	x	
Records for all Measurements	3.3.2.8	5	3.4.3.18.1	14		
Records for Dry Mass Properties Measurements	3.3.2.7	5	3.4.3.18.2	14		
Records for Fluid Mass Properties Measurements	3.3.2.7, 3.3.2.9	5	3.4.3.18.3	14		
Summary of Critical Mass Properties	3.4.2.1.4	7	3.4.3.19	14		x
Evaluation of Flight	3.3.2.9	5	3.4.3.20	14		
Critical Mass Properties Uncertainties	3.3.2.3	4	3.4.3.21	15	x	
Mass Properties Limits	3.3.2.4	4	3.4.3.22	15	x	
Parameters and Inventory of Fluids and Propellants Loaded	3.3.2.1	4	3.4.3.23	15	x	x
Capacity and Loading Information for Fluids and Propellants	3.3.2.1	4	3.4.3.24	15	x	
Mass Properties Verification Plan	3.3.2.5	4	3.4.3.25	16		

NOTES: 1 less item h
+ update only - submit changes to the data, information or analyses contained in the last published report of these iter
(x) submitted as required by procuring activity

Table 1. Report Content and Submittal Schedule (Refer to paragraphs 3.4.1, 3.4.2, and 3.4.3)

Definition		Acquisition												
Detail	Status	Detail				Status						Pro-cedural	Miscellaneous	
3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Semiannually for studies of 1 year or more; at completion of all studies; with submittal of all proposals	Every other week for studies of 2 months or less; at first of each month for studies more than 2 months (to be continued through contract definition)	At PDR, or within 30 days of approved definitive contract or Go-Ahead) FOR APPROVAL)	Annually for contracts exceeding 2 years	At CDR, or within 30 days after 90% completion of original drawing release for contracts of less than 2 years	At FACI, or within 30 days after weighings, or flights, specified by the procuring activity	Design - first of each month after approved definitive contract (or Go-Ahead) and ending with delivery of last item	Pre-flight - 120 days prior to launch	Pre-flight - 14 days after acceptance weighing	Pre-flight - 14 days after significant mass properties change	Post-flight - Quick Look - within 24 hours after launch	Post-flight - Final - 30 days after launch	Verification Plan - within 6 months after definitive contract (or Go-Ahead) (FOR APPROVAL)	Contract Change Proposal - with each contract change proposal	Fluid and Propellant Verification - as required by Verification Plan
x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
x		x	x	x										
x	x	x	x	x	x	x	x	x	x		x			
x		x	x	x	x									
x	x	x	x	x	x	x	x	x	x		x			
	x					x	x	x	x				x	
	x					x								
	x					x	x	x	x	x	x			
					x		x	x	x		x			
x	x	x	x	x	x	x	x	x	x	x	x			
x		x	x	x	x									
x	x	x	x	x	x	x	x[1]	x[1]	x[1]		x[1]			
x		x											x	
x		x	x	x	x	+	+	+	+		x			
		(x)	(x)	(x)	(x)	(x)								
x		x	x	x	x									
x		x	x	x	x	+								
x		x	x		x									
					x			x			x			x
					x			x						
										x	x			x
	x					x	x	x	x	x	x			
										x	x			
x		x	x	x	x	+								
x		x	x	x	x	+								
x	x	x	x	x	x	x	x	x	x	x	x			
x		x	x	x	x	+								
						+						x		

Appendix A

This appendix contains sample forms to be used as a guide in the construction and use of forms as discussed in paragraph 3.4.2.1.2.

MASS PROPERTIES SUMMARY

CODE	DESCRIPTION	SPECIFIED WEIGHT BASE ( )	PROCURING ACTIVITY AND GFE CHANGES	REVISED SPECIFIED WEIGHT BASE	CURRENT WEIGHT	CHANGES LAST TO CURRENT	PERCENTAGE BREAKDOWN OF CURRENT WEIGHT			NOTE NUMBER
							EST	CALC	ACT	

PREPARED BY _____ IDENTIFICATION REPORT NO. _____

DATE _____ PAGE ___ OF _____

FORM 1 PART 1

MASS PROPERTIES SUMMARY									
CODE	DESCRIPTION	CURRENT WEIGHT ( )	CENTER OF GRAVITY (____ FROM REF. DATUM)			MOMENT OF INERTIA (_____)		
			X	Y	Z	PITCH	ROLL	YAW

PREPARED BY _____ IDENTIFICATION REPORT NO. _____
DATE _____ PAGE ____ OF _____

FORM 1 PART II

DETAIL MASS PROPERTIES

CODE	DESCRIPTION	CLASS (E, C, A)	WEIGHT (_____) CODE GENERATION			CENTER OF GRAVITY (___ FROM REF. DATUM)		
			FIRST	SECOND	THIRD	X	Y	Z

PREPARED BY _____ IDENTIFICATION REPORT NO. _____

DATE _____ PAGE ___ OF _____

FORM 2 PART I

DETAIL MASS PROPERTIES									
CODE	DESCRIPTION	CURRENT WEIGHT ( ) CODE GENERATION			MOMENT OF INERTIA ( )			NOTE NUMBER
		FIRST	SECOND	THIRD	PITCH	ROLL	YAW	

PREPARED BY _____ IDENTIFICATION REPORT NO. _____
DATE _____ PAGE ____ OF _____

FORM 2 PART II

MASS PROPERTIES CHANGE ANALYSIS

*CHANGE IDENTIFICATION AND/OR *NOTE NUMBER	CODE	EFFECTIVE POINT	WEIGHT CHANGE ( )			CENTER OF GRAVITY (__ FROM REF. DATUM)			MOMENT OF INERTIA (_____)		
			TOTAL	RESPONSIBILITY							
				DESIGN ACTIVITY	PROCURING ACTIVITY	X	Y	Z	PITCH	ROLL	YAW

PREPARED BY _____ IDENTIFICATION REPORT NO. _____

DATE _____ PAGE ____ OF _____

FORM 3 PART I *NOTE: Cross out if not applicable

MASS PROPERTIES CHANGE ANALYSIS			
*CHANGE IDENTIFICATION AND/OR *NOTE NUMBER	CODE	TOTAL WEIGHT CHANGE (_____)	REMARKS

PREPARED BY _____ **IDENTIFICATION** REPORT NO. _____
DATE _____ PAGE ____ OF _____

FORM 3 PART II *NOTE: Cross out if not applicable.

WEIGHT AND BALANCE HISTORY LOG Sheet No. _____

Place an X in blanks not required for identification

ITEM SPACE VEHICLE _____ S/C MODULE _____ ENGINE MODEL _____

MISSION _____ L/V STAGE _____ SERIAL NO. _____

ENTRY NO.	DATE / TIME	SIGNATURE	ITEM DESCRIPTION (DWG NO, SERIAL NO, NAME, SYSTEM)	CODE	+ / -	WEIGHT (____)	CENTER OF GRAVITY (____ FROM REF DATUM)		
							X	Y	Z

FORM 4 PART I

WEIGHT AND BALANCE HISTORY LOG

Sheet No. ____

WORK SHEET

Place an X in blanks not required for identification

ITEM

SPACE VEHICLE _____ S/C MODULE _____ ENGINE MODEL _____

MISSION _____ L/V STAGE _____ SERIAL NO. _____

ENTRY NO.	+ / -	WEIGHT (_____)	CENTER OF GRAVITY			PRODUCT OF INERTIA			TRANSFER FACTORS			MOMENT OF INERTIA ( )			MOMENT OF INERTIA ( )		
			X	Y	Z	WXY	WXZ	WYZ	X^2	Y^2	Z^2	Ioy	Iox	Ioz	PITCH	ROLL	YAW

FORM 4 PART II

SEQUENCED MASS PROPERTIES DATA

CODE	DESCRIPTION	CURRENT WEIGHT ( )	CENTER OF GRAVITY (FROM REF. DATUM)			MOMENT OF INERTIA ( )			NOTE NUMBER
			X	Y	Z	PITCH	ROLL	YAW	

PREPARED BY_____
DATE_____

IDENTIFICATION

REPORT NO._____
PAGE____ OF_____

Form 5

APPENDIX B

FUNCTIONAL CODE

B.10.0 OBJECTIVES

The functional code provides a coding system for a three-generation breakdown of vehicle items according to their functional use. The objectives of the functional code are:

a. Provide a basis for computing weight summaries.

b. Allow direct substantiation of weight summaries and analysis methods.

c. Provide a uniform basis for design weight comparison of vehicle systems.

d. Facilitate the preparation of weight summaries for complete vehicles such that a given section, stage, or module summary may be readily included in the summary of the total vehicle.

e. Provide identifiable vehicle coordinate location data.

B.20.0 GENERAL DESCRIPTION

The functional code, along with the nomenclature employed, shall be considered as the basic functional breakdown of vehicle items. Using this code, any type of vehicle may be coded for the purpose of mass properties reporting. The code consists of first generation items, each of which is broken down into second generation items. The second generation items are further broken down into third generation items. The first 16 first-generation codes include items which are essentially fixed in location and weight, the summary of which is dry weight. The remaining first generation codes include items which are variable either in location or weight. The functional code is intended to be complete, with the exception of the third generation breakdown. The third generation items listed in the code are intended to serve as a guide and do not necessarily represent a complete or fixed third generation breakdown. Further structural and equipment breakdowns, and the generous use of footnotes, are encouraged when such practices will further the understanding of tabulated data and aid in the intended purposes. The use of the words "provision" and "installation" shall be avoided unless further breakdown is given to indicate what is included in the item.

B.30.0 USAGE

All coding shall use the functional code system. Each identifiable section, stage or module shall be coded separately. When coding items, the design activity shall not deviate from the first generation breakdown. When necessary, second generation items may be added, if prior approval has been obtained from the procuring activity. The third generation breakdown identifies the second generation, and may be modified or expanded as required as long as the identity of the second generation is not changed and sufficient detail is provided such that a multistation analysis may be validated. It may be practical in some instances to code complete assemblies, but in such cases, the items making up the assembly shall not be coded. Once an item has been coded, the code shall not be changed without the approval of the procuring activity.

B.30.1 Items Jettisoned During Flight. - All items allocated to dry weight that are jettisoned or ablated during flight shall be noted and identified.

B.30.2 Attachment and Support Items.- All loose items of attachment equipment and system supports (nuts, bolts, rivets, etc.), shall be allocated to the same group as the item being attached or supported. Multipurpose supports shall be allocated to the primary function. Where a primary allocation cannot be determined by observation, such as may occur for fairings, fairleads, supports for wire harness, brackets, etc., an arbitrary allocation may be made.

B.30.3 Dual Allocations.- Where provisions are made in both dry weight and variable load categories for a given installation, allocations shall be made to the dry weight or variable load in accordance with the category allocation assigned in the model or detail specification or in the general design specification and/or instructions of the procuring activity. If a conflict in category allocation of any items occurs between the weight statement and model or detail specification, the latter shall govern in all cases.

B.30.4 Power Distribution Systems.- All items of power distribution systems (electrical, hydraulic, and pneumatic), including fluid in the respective tubing for hydraulic systems, from main distribution points to actuating units shall be allocated with the items operated. All components from source of power to main distribution points shall be considered to comprise the main system. The distribution system for a given item shall be assumed to include all components which would be unnecessary and could be removed if power actuation of the item were to be eliminated. Where several successive branches from a distribution system are involved, and a clear-cut main distribution point is not readily apparent, it shall be assumed that power is supplied to a given geographic location primarily for the function requiring the largest power, and to other functions in the sequence of descending power requirements.

B.30.5 Items Performing Multipurpose Functions.- Items which cannot be isolated as serving a single function, and which are integral with the structure of aerodynamic surfaces or body, shall be allocated to the appropriate structural group. Typical in this category are:

a. Ducting for air supply, bleed air and exhaust in which skin or webs serve as part of the duct contour. The duct wall and stiffeners which can be isolated primarily as duct systems are allocated to Main Propulsion - Air Breathing - Air Induction System or to Environmental Control.

b. Integral tanks in which skin, webs, solid bulkheads and load carrying seal fittings are utilized to form the cavity. The separate tank supports, sealant material, nonload carrying fittings are allocated to "Main Propulsion."

c. Skin, ablative material or special material integral with the structure and required for adverse environments, including elevated temperature, shall be included in the structural groups. Nonstructural temperature control systems for structure are allocated to "Induced Environment Protection."

d. Radomes which do not form normal contour of the aerodynamic surface or body are allocated to the "Guidance and Navigation" or "Communication" groups.

e. Removable structural panels or structural doors for special functions are allocated to the basic structural groups.

B.30.6 Items Common to Several Structural Groups.- Items common to several structural groups consist of:

a. Joints, Splices and Fasteners. These items include all doublers, fillers, spacers, gussets, angles, clips, rivets, bolts, nuts, and screws that should, insofar as practicable, be allocated to the structural function served.

b. Bulkheads, Frames, Cover, and Longerons. Bulkheads are the main structural members which assist in carrying loads around major cutouts, or which distribute major internal or external concentrated loads and may also act as partitions to separate an area into physical compartments. Body bulkheads should be listed individually and identified by location. Frames are similar to bulkheads but usually of relatively lighter construction and serve the function primarily of stiffening the cover or skin to maintain contour under load. Longerons distribute the load longitudinally, along with longitudinal partitions which contribute to body strength.

c. Exterior Finish and Sealer. This includes paint, finish, and sealer for protection from the elements, and is coded to the item it covers.

B.40.0 FIRST GENERATION LISTING AND DESCRIPTION

The following list presents all of the first generation functional code items and a brief description of each. These descriptions shall be used to establish the coding of space vehicle systems and components.

B.40.1 Aerodynamic Surfaces. - The basic and secondary load-carrying members for all primary lifting and aerodynamic control surfaces, both fixed and movable, exclusive of the nonstructural panels used for induced environmental protection systems. The various surfaces are identified as:

a. Leading edge: all structure forward of the front spar.

b. Trailing edge: all structure aft of the rear spar.

Surface-body splices and fittings are to be allocated to the surface.

B.40.2 Body Structure. - The basic and secondary load-carrying members, exclusive of the nonstructural panels used for induced environmental protection systems. Identify, by note, the structure that is jettisoned during flight.

B.40.3 Induced Environment Protection. - The devices which in themselves, or in combination, protect the vehicle structure from the detrimental effects of heat, noise, meteorites and radiation.

B.40.4 Launch, Recovery and Docking. - Items that provide the vehicle with the capability to be launched from or brought to rest with respect to a mass. Enter descriptive or location data, as appropriate, for clarification of the function served.

B.40.5 Main Propulsion. - Propulsive items which provide flight path thrust and acceleration and include rocket engines, nuclear engines, propulsive devices, and related equipment, such as fuel systems, oxidizer systems, and pressurizing systems.

Other propulsion devices, such as those used for electrical power or to maintain control of orientation, are coded elsewhere. Exception -- thrust vectoring systems which are integral with the engine are allocated to the engine.

a. Fluid and Gas Systems Control - list liquid level sensors and any control system, such as propellant-loading gaging system and propellant utilization system, which senses propellant tank levels and transmits appropriate control signals to the engine.

b. Basic Power Plant Control - list controls, including valves which are associated with the start, operation and shutdown of the power plant. These controls are usually supplied by the power plant manufacturer.

c. Solid Propellant Engine and Accessories, Inner and Outer Insulation - list the total weight of each, including that which is burned.

d. Nuclear and Air Breathing Power Plants - (1) Nuclear shielding: list all shielding required for reactor functioning. Shielding for environmental protection is coded in Induced Environmental Protection group. (2) Air breathing: list all air breathing systems such as nacelle, pylon, and engine section, with an adequate structural breakdown (skin, bulkhead, etc.), provided a clear distinction can be made (i.e., not integral with the body structure).

e. Propellant System - list the items that contain and feed the needed propellants to the propulsion unit. As a minor deviation in the normal functional subdivision of the vehicle, the lubrication systems are included with the propellant system.

B.40.6 Orientation Controls, Separation and Ullage.- Control units, exclusive of navigation and guidance, which provide relatively small amounts of thrust or force compared to the main propulsion system, usually for purposes such as velocity control, attitude control, ullage control, rendezvous, and docking. Aerodynamic and spatial controls include the electro-mechanical, hydraulic, or pneumatic actuation system, from the actuator source to the item actuated.

B.40.7 Prime Power Source.- Systems used to generate power for purposes other than propulsion, including the source of initial power. However, once the power has been generated, any additional conversion equipment is listed under the Power Conversion and Distribution group. Indicate if the power source includes an integral pump or generator. All separated pumps or generators are to be included in the Power Conversion and Distribution group (i.e., hydraulic, pneumatic, or electrical).

B.40.8 Power Conversion and Distribution.- Systems used to distribute electrical, hydraulic, or pneumatic power. The source of initial power is included in the Prime Power Source group.

B.40.9 Guidance and Navigation.- This group is divided into the following major subgroups:

a. Guidance Source - receives a sensor signal.

b. Guidance Evaluation - evaluates signals, determines navigation requirements and informs the output systems.

c. Output - activates the control systems.

B.40.10 Instrumentation.- Measuring, signal conditioning, recording, and programming systems for data sampling and recording, including the sensors, circuitry, signal con-

verters, and recording media from the measurement source to a point of telemetry or permanent storage.

B.40.11 Communication.- The equipment required for all means of communication within, emanating from, and received by the missile or space vehicle. This includes such items as transmitters, receivers, antennas, power amplifiers, television cameras, and spares.

B.40.12 Environmental Control.- Controls internal environmental conditions such as temperature, pressure, humidity, atmospheric constituents, and odor for personnel and equipment.

B.40.13 Reserved

B.40.14 Personnel Provisions.- Items within the crew cabin, such as accommodations, fixed life support equipment, cargo handling, furnishings and built-in emergency equipment.

B.40.15 Crew Station Controls and Panels.- Items consisting of crew station controls, pedestals, stands, and display panels for all systems. Actuation of the controls may be accomplished manually or in combination with electronic, hydraulic or pneumatic devices.

B. 40. 16 Range Safety and Abort. - Systems that indicate malfunctions which will endanger personnel or damage equipment. These systems may also initiate remedial action automatically or perform upon command for emergency conditions detected by the system.

B. 40. 17 Personnel. - The crew required to perform a particular mission, including the nonfixed items required to support the crew both inside and outside of the spacecraft, such as personal gear, life support items, and crew accessories.

B. 40. 18 Cargo. - Items stored aboard the spacecraft that will be required to perform certain functions during the mission. These items include scientific instruments and equipment to perform experiments, passengers and associated equipment.

B. 40. 19 Ordnance. - The materials and their immediate containers whose normal function is to detonate or explode.

B. 40. 20 Ballast. - Temporary ballast within the vehicle for purposes of trim. This ballast may be in the form of liquids or solids. Fixed ballast shall be included in dry weight, functional code 2. 13.

B. 40. 21 Residual Propellant and Service Items. - Propellant and service items, remaining in an item, which are not usable.

B. 40. 22 Reserve Propellant and Service Items. - Propellant and service items carried by a propulsion stage or module in excess of that required to perform a mission with a nominal vehicle.

B. 40. 23 Inflight Losses. - Propellant losses associated with the use of auxiliary propulsion systems. These include losses for roll and attitude control, venting losses from pressurization gases, and boil-off losses.

B. 40. 24 Thrust Decay Propellant. - Propellant consumed from the specified value of thrust, following the engine cutoff signal, to stage or module separation or to zero value of thrust.

B. 40. 25 Full Thrust Propellant. - Propellant consumed during the burning period from the specified value of thrust following ignition, or from lift-off from the pad, to the specified value of thrust following the cutoff signal.

B. 40. 26 Thrust Buildup Propellant. - Propellant consumed from ignition to the specified value of thrust, or consumed prior to lift-off from the launchpad.

B. 40. 27 Pre-ignition Losses. - Fluid losses associated with starting the primary propulsion system of a stage or module which occur prior to the ignition signal.

B. 50. 0 FUNCTIONAL CODE LISTING

The following pages list the first, second, and third generation breakdown of vehicle items. As discussed in par. B. 20. 0, the third generation items are intended to serve as a guide and do not necessarily represent a complete or fixed third generation breakdown.

FUNCTIONAL CODE

FIRST-GENERATION LISTING

1. Aerodynamic Surfaces
2. Body Structure
3. Induced Environment Protection
4. Launch, Recovery and Docking
5. Main Propulsion
6. Orientation Controls, Separation and Ullage
7. Prime Power Source
8. Power Conversion and Distribution
9. Guidance and Navigation
10. Instrumentation
11. Communication
12. Environmental Control
13. Reserved
14. Personnel Provisions
15. Crew Station Controls and Panels
16. Range Safety and Abort
17. Personnel
18. Cargo
19. Ordnance
20. Ballast
21. Residual Propellant and Service Items
22. Reserve Propellant and Service Items
23. Inflight Losses (Liftoff to Separation)
24. Thrust Decay Propellant
25. Full Thrust Propellant
26. Thrust Propellant Buildup
27. Pre-Ignition Losses

FUNCTIONAL CODE

FIRST GENERATION	1. AERODYNAMIC SURFACES
SECOND GENERATION	THIRD GENERATION
1.1 Fixed Surfaces	Basic structure Leading edge Trailing edge Secondary structure Trim devices Insulation Exterior finish and sealer
1.2 Movable Surfaces	Basic structure Leading edge Trailing edge Secondary structure Trim devices Insulation Exterior finish and sealer
1.3 Fairings and Associated Structure (Including Insulation)	Forward fairings Center fairings Tail fairings Air intakes Cable conduits Ice shields Equipment fairings Exterior finish and sealer
1.19 Contingency	
1.20 Growth	

FUNCTIONAL CODE

FIRST GENERATION	2. BODY STRUCTURE
SECOND GENERATION	THIRD GENERATION
2.1 Structural Fuel Tank	Skin (including welds) Ring frames, stringers, longerons, struts, and tie rods Beams and shear panels Forward bulkhead Aft bulkhead Fittings Brackets, doublers, gussets, etc. Cutouts and associated structure Container wall insulation - inner Container wall insulation - outer Forward bulkhead insulation - inner Forward bulkhead insulation - outer Aft bulkhead insulation - inner Aft bulkhead insulation - outer Antislosh devices
2.2 Structural Oxidizer Tank	Skin (including welds) Ring frames, stringers, longerons, struts, and tie rods Beams and shear panels Forward bulkhead Aft bulkhead Fittings Brackets, doublers, gussets, etc. Cutouts and associated structure Container wall insulation - inner Container wall insulation - outer Forward bulkhead insulation - inner Forward bulkhead insulation - outer Aft bulkhead insulation - inner Aft bulkhead insulation - outer Antislosh devices
2.3 Structural Propellant Tank (Common Bulkhead)	Skin (Including welds) Ring frames, stringers, longerons, struts, and tie rods Beams and shear panels Forward bulkhead Common bulkhead (including insulation) Aft bulkhead Fittings Brackets, doublers, gussets, etc. Cutouts and associated structure Container wall insulation - inner Container wall insulation - outer Forward bulkhead insulation - inner Forward bulkhead insulation - outer Aft bulkhead insulation - inner Aft bulkhead insulation - outer Antislosh devices

FUNCTIONAL CODE

FIRST GENERATION	2. BODY STRUCTURE (Cont'd)
SECOND GENERATION	THIRD GENERATION
2.4 Structural Solid Propellant Case or Tank	Forward closure assembly Cylinder assembly Aft closure assembly Nozzle adapter Attaching assemblies Insulation
2.5 Structure Enclosing Nonintegral Tanks	Skin (including welds) Ring frames, stringers, longerons, struts, and tie rods Beams and shear panels Bulkheads Fittings Brackets, doublers, gussets, etc. Cutouts and associated structure Insulation - inner Insulation - outer Platforms and catwalks
2.6 Structure Forward of Integral Tanks	Skin (including welds) Ring frames, stringers, longerons, struts, and tie rods Beams and shear panels Bulkheads Fittings Brackets, doublers, gussets, etc. Cutouts and associated structure Insulation - inner Insulation - outer Platforms and catwalks
2.7 Structure Between Integral Tanks	Skin (including welds) Ring frames, stringers, longerons, struts, and tie rods Beams and shear panels Bulkheads Fittings Brackets, doublers, gussets, etc. Cutouts and associated structure Insulation - inner Insulation - outer Platforms and catwalks
2.8 Structure Aft of Integral Tanks	Skin (including welds) Ring frames, stringers, longerons, struts, and tie rods Beams and shear panels Bulkheads Fittings Brackets, doublers, gussets, etc.

FUNCTIONAL CODE

FIRST GENERATION	2. BODY STRUCTURE (Cont'd)
SECOND GENERATION	THIRD GENERATION
2.8 Structure Aft of Integral Tanks (cont'd)	Cutouts and associated structure Insulation - inner Insulation - outer Platforms and catwalks
2.9 Thrust Structure	Skin (including welds) Ring frames, stringers, longerons, struts, and tie rods Beams and shear panels Bulkheads Fittings Brackets, doublers, gussets, etc. Cutouts and associated structure Hold-down posts Insulation
2.10 Interstage/Spacer/ Vehicle Instrument Unit Structure	Skin (including welds) Ring frames, stringers, longerons, struts, and tie rods Beams and shear panels Bulkheads Fittings Brackets, doublers, gussets, etc. Cutouts and associated structure Insulation - inner Insulation - outer Platforms and catwalks
2.11 Pressurized Compartment	Bulkheads Rings Webs Frames Longerons Stringers Covering (skin, including welds) Reinforcements Partitions Floor (acting as structural member) Hatches and airlocks Windows and ports Firewalls Pressure seals Brackets, doublers, gussets, etc.
2.12 Nonpressurized Compartment	Bulkheads Rings Webs Frames Longerons Stringers Covering (skin, including welds)

FUNCTIONAL CODE

FIRST GENERATION	2. BODY STRUCTURE (Cont'd)
SECOND GENERATION	THIRD GENERATION
2.12 Nonpressurized Compartment (cont'd)	Reinforcements Partitions Floors (acting as structural member) Hatches and airlocks Windows and ports Firewalls Pressure seals Brackets, doublers, gussets, etc.
2.13 Ballast	Ballast for longitudinal center of gravity control Ballast for radial center of gravity control Ballast for weight simulation
2.14 Multipurpose Equipment-Containers, Panels Supports	
2.15 Exterior Finish and Sealer	
2.19 Contingency	
2.20 Growth	

FUNCTIONAL CODE

FIRST GENERATION	3. INDUCED ENVIRONMENT PROTECTION
SECOND GENERATION	THIRD GENERATION
3.1 Thermal Protection (Active)	Ablator Insulation Reinforcements Release mechanism Fairings Attaching structure Bonding material
3.2 Thermal Protection (Passive)	Insulation Reinforcements Release mechanism Fairings Attaching structure Bonding material
3.3 Noise Protection	Insulation Attaching structure Bonding material
3.4 Meteorite Protection	Bumper Supports Stiffeners Filler Shield Attaching structure
3.5 Radiation Protection	Shielding Attaching structure
3.19 Contingency	
3.20 Growth	

FUNCTIONAL CODE

FIRST GENERATION	4. LAUNCH, RECOVERY, AND DOCKING
SECOND GENERATION	THIRD GENERATION
4.1 Launch Gear	Struts Pads Fittings Deploying devices Sequencing devices Controls Braces Power source Shock attenuation devices Structure Attachment fittings Tie-down fittings
4.2 Deployable Aerodynamic Devices	Drogue parachute Main parachute Pilot parachute Paraglider Structure Sequencing controls
4.3 Landing Gear	Struts Pads Fittings Deploying devices Sequencing devices Controls Braces Power source Shock attenuation devices Solid brake rocket cases Liquid brake rockets Structure
4.4 Flotation Gear	Container Flotation devices Power source Control devices Sequencing devices Deployment devices Structure
4.5 Docking Structure	Rings Seals Latching mechanisms Repositioning devices Separation devices Fairings

FUNCTIONAL CODE

FIRST GENERATION	4. LAUNCH, RECOVERY, AND DOCKING (Cont'd)
SECOND GENERATION	THIRD GENERATION
4.6 Recovery Aids	Visual Communication Tracking Landing Structure
4.19 Contingency	
4.20 Growth	

FUNCTIONAL CODE

FIRST GENERATION	5. MAIN PROPULSION
SECOND GENERATION	THIRD GENERATION
5.1 Liquid Rocket Engine and Accessories	Thrust chamber Turbopump Engine mounts (attached to engine) Gimbal mounts and thrust frame (attached to engine) Propellant plumbing (attached to engine) Gas generator and igniter (less ordnance) Lubrication system Controls Hydraulic system Pneumatic system Electrical system Heat exchangers and exhaust ducts Purge system
5.2 Solid Propellant Engine and Accessories	Nozzle - fixed Nozzle - movable Propellant container (nonstructural) Engine attachment fittings Igniter (less ordnance) Controls Insulation - inner Insulation - outer Safe and arm system (less ordnance) Thrust termination system (less ordnance)
5.3 Nuclear Power Plant and Accessories	Propellant feed system (including turbopump attached to engine) Reactor (including shielding) Thrust chamber (including nozzle) Thrust structure (attached to engine) Cooling system Controls Pneumatic system Hydraulic system Destruct system (less ordnance)
5.4 Ion Engine and Accessories	Propellant feed system (attached to engine, including turbopump) Reactor (including shielding) Thrust chamber (including nozzle) Thrust structure (attached to engine) Cooling system Pneumatic system Hydraulic system Turbine Power generating system Destruct system (less ordnance)

FUNCTIONAL CODE

FIRST GENERATION	5. MAIN PROPULSION (Cont'd)
SECOND GENERATION	THIRD GENERATION
5.5 Photon Engine and Accessories	Power source Light source Reflector Destruct system (less ordnance) Controls
5.6 Air Breathing Engine and Accessories	Propellant feed system Thrust structure Thrust chamber Turbine Compressor Controls Air induction
5.7 Purge System for Stage Chilldown	Bottles and supports Valves and nozzles Controls Plumbing and fittings Manifolds Ducts for chilldown or purge gas (including brackets and attaching hardware) Buckets or collectors for disposal
5.8 Fuel Container (Nonstructural)	Structure Baffling and antivortex webs Liners Bladders Fill and drain provisions Vents Sumps Sensors Supports Insulation
5.9 Fuel System	Pump installation (including power supply attached to engine) Fill and drain system Distribution or suction system Replenishing system (if separate) Transfer system Vent system Purge system Antivortex devices Exclusion risers Sensing controls
5.10 Pressurization System - Fuel	Tank structure Supports Fill and drain provisions Vents Sumps

FUNCTIONAL CODE

FIRST GENERATION	5. MAIN PROPULSION (Cont'd)
SECOND GENERATION	THIRD GENERATION
5.10 Pressurization System - Fuel (cont'd)	Sensors Plumbing Valves and regulators Insulation Heat exchanger Sensing controls
5.11 Oxidizer Container (Nonstructural)	Structure Baffling and antivortex webs Liners Bladders Fill and drain provisions Vents Sumps Sensors Supports Insulation
5.12 Oxidizer System	Pump installation including power supply (not attached to engine) Fill and drain system Distribution or suction system Replenishing system (if separate) Transfer system Vent system Purge system (if separate) Antivortex devices Exclusion risers Sensing controls
5.13 Pressurization System - Oxidizer	Tank structures Supports Fill and drain provisions Vents Sumps Sensors Plumbing Valves and regulators Insulation Heat exchanger Sensing controls
5.14 Auxiliary Fluids System	Tanks and supports (not integral with structure) Pump installation including power supply (not attached to engine) Fill and drain system Distribution or suction system Replenishing system (if separate) Transfer system Vent system

FUNCTIONAL CODE

FIRST GENERATION	5. MAIN PROPULSION (Cont'd)
SECOND GENERATION	THIRD GENERATION
5.14 Auxiliary Fluids System (cont'd)	Tank pressurization system Purge system (if separate) Antivortex devices Exclusion risers Sensing controls
5.15 Propellant Utilization System	Plumbing Valves Regulators Supports
5.16 Lubricating System	Tanks, tubing, valves, accumulators, bottles, supports, etc. Controls Power supply (if separate) Wiring, cables (including clamps, hardware, etc.)
5.19 Contingency	
5.20 Growth	

FUNCTIONAL CODE

FIRST GENERATION	6. ORIENTATION CONTROLS, SEPARATION, AND ULLAGE
SECOND GENERATION	THIRD GENERATION
6.1 Thrust System (Main)	Thruster Injection system Gimbal system (if not integral) Insulation Protective devices Case Liner Ignition system (less ordnance) Nozzles Structure
6.2 Thrust System (Auxiliary)	Thruster Injection system Gimbal system (if not integral) Insulation Protective devices Case Liner Ignition system (less ordnance) Nozzles Structure
6.3 Aerodynamic Control	Roll Pitch Yaw
6.4 Spatial Control	Roll Pitch Yaw Stabilizing electronics
6.5 Separation	Structure Rocket cases Fairings Controls, sequencing equipment, and wiring Jettison system Power supply
6.6 Ullage (Separate from 6.4, 6.5)	Structure Rocket cases Fairings Controls, sequencing equipment, and wiring
6.7 Fuel Containers	Tanks Bladders Baffles Fill and drain provisions Sensors and valves Insulation Structure

FUNCTIONAL CODE

FIRST GENERATION	6. ORIENTATION CONTROLS, SEPARATION, AND ULLAGE (Cont'd)
SECOND GENERATION	THIRD GENERATION
6.8 Oxidizer Containers	Tanks Bladders Baffles Fill and drain provisions Sensors and valves Insulation Structure
6.9 Pressurization	Tanks Liners Fill and drain provisions Insulation Plumbing Sensors and valves Sequencing Structure
6.10 Distribution and Control - Fuel	Plumbing Valves and regulators (indicate injection valves) Insulation Structure
6.11 Distribution and Control - Oxidizer	Plumbing Valves and regulators (indicate injection valves) Insulation Structure
6.12 Thrust Structure	Ring Frame Supports Fittings Skin Insulation Stringers
6.13 Artificial Gravity	
6.19 Contingency	
6.20 Growth	

FUNCTIONAL CODE

FIRST GENERATION	7. PRIME POWER SOURCE
SECOND GENERATION	THIRD GENERATION
7.1 Power Source -	Engine Engine pump unit Engine generator unit Gas generator unit Gas generator Fuel storage Plumbing Valves and pumps
7.2 Power Source - Fuel Cell	Fuel cell - nonregenerative modules and internal voltage controls Fuel container Oxidizer container Reactant controls - H_2 (including plumbing, heat exchangers, etc.) Reactant controls - O_2 (includes plumbing, heat exchangers, etc.) Plumbing and valves Radiator, nonstructural (area) Electrical controls - coolant, reactant Pumps - coolant Structure Purge system Electrical coupling system (integral)
7.3 Power Source - Batteries	Battery (quantity)* Battery container and supports Voltage controls Recharge controls Structure Electrical coupling system (integral) Emergency *Identify system usage
7.4 Power Source - Solar Cell	Solar cell Intercell wiring Protective diodes (short regulators, etc.) Protective covers and filters Insulation and coatings Reflector Mounting panel or structure (solar paddle, etc.) Structure (including deployment devices) Orienting devices and controls Voltage controls Cooling system Electrical coupling system (integral) Photometric monitoring device

FUNCTIONAL CODE

FIRST GENERATION	7. PRIME POWER SOURCE (Cont'd)
SECOND GENERATION	THIRD GENERATION
7.5 Power Source - Nuclear	Reactor or isotope source Radiation shield Primary systems (tubing, heaters, pumps) Power converter (rotating unit, boiler, structure, regulator, radiator) Heat rejection structure Electrical startup and controls Flight instrumentation (speed, etc.) Destruct system (less ordnance) Structure
7.6 Power Source - Gas Generator	Pressurization tank (force feed system) Pressurization controls (force feed system) Fuel containers Fuel controls Plumbing Valves and controls Decomposition chamber Speed regulator Gas bearing Gear box Turbine Heat exchanger Structure Purge system Voltage control Electrical coupling system (integral)
7.19 Contingency	
7.20 Growth	

FIRST GENERATION	8. POWER CONVERSION AND DISTRIBUTION
SECOND GENERATION	THIRD GENERATION
8.1 Power Conversion - Electrical (AC)	Generator Transformers Inverters Phase adapters Frequency converters Voltage regulators Constant speed drive Supports
8.2 Power Conversion - Electrical (DC)	Generator Converters Voltage regulators Rectifiers Supports
8.3 Power Conversion - Hydraulic/Pneumatic	Motor pump or compressor Pump or compressor unit (unless integral) Reservoirs Accumulators Filters Pressure regulator Supports
8.4 Power Distribution - Electrical (AC)	Buses Isolator assembly Circuit breakers and switches Relays Electrical coupling Supports
8.5 Power Distribution - Electrical (DC)	Buses Isolation diode system Circuit breakers and switches Relays Electrical coupling Supports
8.6 Power Distribution - Hydraulic/Pneumatic	Valves Controls Plumbing Fluid Supports
8.7 Utility Provisions - Electrical	Pyrotechnic initiator Lights Signal devices
8.8 External Service Provisions (Type Power __)	
8.19 Contingency	
8.20 Growth	

FUNCTIONAL CODE

FIRST GENERATION	9. GUIDANCE AND NAVIGATION
SECOND GENERATION	THIRD GENERATION
9.1 Guidance Source - Inertial Reference Stellar Reference Planetary Reference Relative Reference	Programmer Accelerometers Gyros Telescope Sextant Horizon sensor Radar altimeter Rendezvous radar Rendezvous laser Optical sightline sensor Supports
9.2 Guidance Evaluation	Computer Computer keyboard Inertial platform Coupling unit Power and servo assembly Time base selector Gyro electronics Supports
9.3 Output	Electronics package Rate gyros Accelerometers Servo amplifiers Power supply Electrical coupling Supports
9.4 Spares	
9.19 Contingency	
9.20 Growth	

FUNCTIONAL CODE

FIRST GENERATION	10. INSTRUMENTATION
SECOND GENERATION	THIRD GENERATION
10.1 Sensors	Temperature Pressure Flow Volume Leak rate Acceleration Force Vibration Displacement Angular velocity Gas partial pressure Acoustic noise Strain Char and ablation Contamination Bio-medical Structure
10.2 Signal Conditioning	Analog commutator Analog-digital converter Digital commutator Programmer Calibrator Signal conditioning Data storage Structure
10.3 Signal Transmission	Antenna Waveguides Coax Transmitters Structure
10.4 Electrical Coupling	Junction box Cable harness Wire Coax Conduit Clips, clamps, etc. Structure
10.5 Support Items	
10.6 Spares	
10.19 Contingency	
10.20 Growth	

FUNCTIONAL CODE

FIRST GENERATION	11. COMMUNICATION
SECOND GENERATION	THIRD GENERATION
11.1 Intercommunication	Transceiver equipment Antenna system Structure
11.2 Near Earth Communication	VHF FM transmitter equipment VHF AM tranceiver equipment VHF antenna system Structure
11.3 Deep Space Communication	DSIF receiver equipment DSIF transmitter equipment DSIF power amplifier equipment DSIF antenna system Structure
11.4 TV Systems	Cameras Monitor Control equipment and components Structure
11.5 Tracking System	
11.6 Spares	Intercommunication Near earth Deep space Tracking system Television system
11.7 Electrical Coupling	Junction box Cable harness Wire Coax Conduit Clips, clamps, etc.
11.8 Racks & Supports	
11.19 Contingency	
11.20 Growth	

FUNCTIONAL CODE

FIRST GENERATION	12. ENVIRONMENTAL CONTROL
SECOND GENERATION	THIRD GENERATION
12.1 ECS - Equipment	Insulation Instrument temperature control system Electronic equipment temperature control system Compartment temperature control system Compartment pressurization system Engine cooling system (separate from engine) Fire control system Electrical coupling system Supports
12.2 ECS - Personnel	Insulation Temperature control system Atmosphere control system Pressurization control system Fire control system Electrical coupling system CO_2 and odor removal system Supports
12.3 Coolant System	Insulation Radiator Fluid boiler Plumbing and valves Blowers Heat exchangers Pumps Containers Supports
12.4 Multipurpose Equipment – Containers, Panels, etc.	Supports
12.19 Contingency	
12.20 Growth	

FUNCTIONAL CODE

FIRST GENERATION	13. RESERVED
SECOND GENERATION	THIRD GENERATION

FUNCTIONAL CODE

FIRST GENERATION	14. PERSONNEL PROVISIONS
SECOND GENERATION	THIRD GENERATION
14.1 Accommodations for Personnel	Seats Supports Restraints - seat Liners Shock absorbers Adjustment mechanisms Bunks Sleeping restraints
14.2 Fixed Life Support Equipment	Food containers Water containers Waste management Hygiene equipment Galley equipment
14.3 Cargo Handling	Rails Attachment fittings
14.4 Furnishings	Partitions Soundproofing Flooring (nonstructural) Lifts and hoist Stairs and ladders Platforms Catwalks
14.5 Emergency Equipment	Fire extinguisher (built-in) Fire detection Life raft provisions Life raft (built-in)
14.19 Contingency	
14.20 Growth	

FUNCTIONAL CODE

FIRST GENERATION	15. CREW STATION CONTROLS AND PANELS
SECOND GENERATION	THIRD GENERATION
15.1 Pedestal	Orientation, separation and ullage Propulsion Environment Navigation and guidance Prime power source Communication Instrumentation Range safety and abort
15.2 Control Stands	Orientation, separation and ullage Propulsion Environment Navigation and guidance Prime power source Communication Instrumentation Range safety and abort
15.3 Instrument Panels	Orientation, separation and ullage Propulsion Environment Navigation and guidance Prime power source Communication Instrumentation Range safety and abort
15.4 Crew Station Controls (Flight)	Control - roll - pitch - yaw Connecting members for above Supports
15.19 Contingency	
15.20 Growth	

FUNCTIONAL CODE

FIRST GENERATION	16. RANGE SAFETY AND ABORT
SECOND GENERATION	THIRD GENERATION
16.1 Sensors	
16.2 Signal Conditioning	
16.3 Signal Transmission	
16.4 Signal Evaluation	
16.5 Destruct System	Destruct receiver Range safety beacon Power supply Controls Supports
16.6 Electrical Coupling System	
16.7 Service Items	
16.8 Spares	
16.9 Debris, Re-entry	
16.19 Contingency	
16.20 Growth	

FUNCTIONAL CODE

FIRST GENERATION	17. PERSONNEL
SECOND GENERATION	THIRD GENERATION
17.1 Crew	Crew Constant wear garments Personnel comm. headset and belt pack Pressure suit
17.2 Personal Gear	Portable life support system Garments - protective Personal parachutes Hygienic equipment Privacy curtains
17.3 Life Support	Food Food containers (portable) Water Water drinking device Water containers (portable) Galley equipment (portable) Recreation equipment Exercise equipment Medical and first aid equipment Survival kit (portable)
17.4 Crew Accessories	Maps and manuals Log book Maintenance tools Fire extinguisher (portable)

FUNCTIONAL CODE

FIRST GENERATION	18. CARGO
SECOND GENERATION	THIRD GENERATION
18.1 Scientific Instruments	
18.2 Experiments	
18.3 Cargo	

FUNCTIONAL CODE

FIRST GENERATION	19. ORDNANCE
SECOND GENERATION	THIRD GENERATION
19.1 Propulsion Ordnance	Igniters Safe and arm Thrust termination Destruct
19.2 Orientation Controls, Separation and Ullage	Igniters (thrust systems) Separation
19.3 Prime Power Source	Destruct (nuclear systems)
19.4 Reserved	
19.5 Range Safety and Abort	Destruct (vehicle)

FUNCTIONAL CODE

FIRST GENERATION	20. BALLAST
SECOND GENERATION	THIRD GENERATION

FUNCTIONAL CODE

FIRST GENERATION	21. RESIDUAL PROPELLANT AND SERVICE ITEMS
SECOND GENERATION	THIRD GENERATION
21.1 Fuel Pressurizing Gas - As Container Residual	
21.2 Oxidizer Pressurizing Gas - As Container Residual	
21.3 Fuel Trapped - Main Engine	Tank Lines - between sump and engine pumps Engine - below pump inlet Sump Fill lines
21.4 Oxidizer Trapped - Main Engine	Tank Lines - between sump and engine pumps Engine - below pump lines Sump Fill lines
21.5 Fuel - Outage Main Engine	
21.6 Oxidizer - Outage Main Engine	
21.7 Fuel Trapped - Auxiliary Propulsion System	Tank Lines Engine
21.8 Oxidizer Trapped - Auxiliary Propulsion System	Tank Lines Engine
21.9 Fuel - Outage Auxiliary Propulsion System	
21.10 Oxidizer - Outage Auxiliary Propulsion System	

FUNCTIONAL CODE

FIRST GENERATION	21. RESIDUAL PROPELLANT AND SERVICE ITEMS (Cont'd)
SECOND GENERATION	THIRD GENERATION
21.11 Fuel Trapped - Electrical Power	Tank Lines Converter
21.12 Oxidizer Trapped - Electrical Power	Tank Lines Converter
21.13 Service Items Trapped - Including Non-expendables	Pressurizing gases (not in propellant tanks) Purge system gases Pneumatic system gases Air-bearing system gases Ejection system gases Hydraulic fluid Lubricants Fuel additives Environment control fluids Spatial attitude control propellants Propellants for landing or recovery

FUNCTIONAL CODE

FIRST GENERATION	22. RESERVE PROPELLANT AND SERVICE ITEMS
SECOND GENERATION	THIRD GENERATION
22.1 Fuel Pressurizing Gas Reserves	
22.2 Oxidizer Pressurizing Gas Reserves	
22.3 Fuel - Main Engine Reserve	
22.4 Oxidizer - Main Engine Reserve	
22.5 Fuel Pressurizing Gas Reserves Auxiliary Propulsion Systems	
22.6 Oxidizer Pressurizing Gas Reserve - Auxiliary Propulsion Systems	
22.7 Fuel Reserves - Auxiliary Propulsion Systems	
22.8 Oxidizer Reserves - Auxiliary Propulsion Systems	
22.9 Fuel - Electrical Power Reserve	
22.10 Oxidizer - Electrical Power Reserve	
22.11 Fuel - Atmospheric Cruise	

FUNCTIONAL CODE

FIRST GENERATION	22. RESERVE PROPELLANT AND SERVICE ITEMS (Cont'd)
SECOND GENERATION	THIRD GENERATION
22.12 Oxidizer - Atmospheric Cruise	
22.13 Service Item Reserves	

FUNCTIONAL CODE

FIRST GENERATION	23. INFLIGHT LOSSES (LIFTOFF TO SEPARATION)
SECOND GENERATION	THIRD GENERATION
23.1 Vented Pressuring Gas-Fuel System	
23.2 Vented Pressuring Gas-Oxidizer System	
23.3 Fuel - Auxiliary Propulsion System	Pressure relief losses Normal burning
23.4 Oxidizer - Auxiliary Propulsion System	Pressure relief losses Normal burning
23.5 Fuel - Electrical System	Pressure relief losses Normal burning
23.6 Oxidizer - Electrical System	Pressure relief losses Normal burning
23.7 Service Items	Pressurizing gases (not in propellant tanks) Purge system gases Pneumatic system gases Air-bearing system gases Ejection system gases Hydraulic fluid Lubricants Fuel additives Environmental control fluids Spatial attitude control propellants Frost Separation system propellants Ullage system propellants

FUNCTIONAL CODE

FIRST GENERATION	24. THRUST DECAY PROPELLANT
SECOND GENERATION	THIRD GENERATION
24.1 Fuel - Consumed During Thrust Decay	Container Sumps Lines Engines
24.2 Oxidizer - Consumed During Thrust Decay	Container Sumps Lines Engines
24.3 Solid Propellant - Consumed During Thrust Decay	
24.4 After-Cooling Propellants (Nuclear)	Container Sumps Lines Engines
24.5 Service Items	Pressurizing gases (not in propellant tanks) Purge system gases Pneumatic system gases Air-bearing system gases Ejection system gases Hydraulic fluid Lubricants Fuel additives Environmental control fluids Spatial attitude control propellants Frost Separation system propellants Ullage system propellants

FUNCTIONAL CODE

FIRST GENERATION	25. FULL THRUST PROPELLANT
SECOND GENERATION	THIRD GENERATION
25.1 Fuel	
25.2 Oxidizer	
25.3 Solid Propellants	

FUNCTIONAL CODE

FIRST GENERATION	26. THRUST BUILDUP PROPELLANT
SECOND GENERATION	THIRD GENERATION
26. 1 Fuel	Pressurizing gases Fuel
25. 2 Oxidizer	Pressurizing gases Oxidizer
26. 3 Solid Propellants	
26. 4 Auxiliary Propulsion System	
26. 5 Service Items	

FUNCTIONAL CODE

FIRST GENERATION	27. PRE-IGNITION LOSSES
SECOND GENERATION	THIRD GENERATION
27.1 Fuel	Pressurizing gases Fuel
27.2 Oxidizer	Pressurizing gases Oxidizer
27.3 Prime Power Source	
27.4 Service Items	Purge system gases Pneumatic system gases Air-bearing system gases Ejection system gases Hydraulic fluid Lubricants Fuel additives Environmental control fluids Spatial attitude control propellants Frost Emergency abort system propellants

APPENDIX C

MASS PROPERTIES DEPENDENT DESIGN INFORMATION

C. 10. 0 GENERAL DESIGN INFORMATION

This appendix lists the major dimensional factors and design criteria used in the development of mass properties estimating techniques and comparative studies (see par. 3. 4. 3. 17.) The following criteria are general design items.

Ballistic coefficient (W/C_dA)
Actual drag coefficient
Mach number
Reynolds number
Lift-to-drag ratio
Type of guidance
Length
Maximum diameter
Width
Depth
Nose radius
Cross sectional area (maximum)
Wetted area
Pressurized body area
Window area
Drag and lift reference area
Total volume
Internal volume
Body volume pressurized
Cone half angle(s)
Stage weight-carrying limitations
Mission duration
Orbit altitudes
Total velocity increment required

C. 20. 0 FUNCTIONAL DESIGN INFORMATION

The following list of design information is intended as a guide for data submittal. Vehicle items are listed in accordance with the first-generation functional code (discussed in Appendix B).

1. Aerodynamic Surfaces (for each surface type)

   Type
   Material(s), types and properties
   Aspect ratio
   Fineness ratio
   Safety factor
   Span
   Theoretical root chord - length
   Theoretical root chord - thickness
   Tip chord - length
   Tip chord - thickness
   Mean aerodynamic chord
   Projected area
   Wetted area
   Sweepback at leading edge
   Sweepback at 25% chord
   Surface loading
   Critical design conditions and resulting critical design loads

2. Body Structure (for each major structural entity)

Type of structure (pressurized, monocoque, skin, stringer, etc.)
Material(s), types and properties
Safety factor
Length
Diameter
Skin thickness
Gross tank volumes
Tank design pressures
Maximum available volume for ballast
Design temperature
Maximum expected operating pressure
Center of pressure location and static margin
Critical design conditions and resulting critical design loads

3. Induced Environmental Protection (for each major environmental entity)

Material(s), types and properties
Manufacturing technique
Application method
Safety factor (value and definition)
Thicknesses
Gross area
Critical design conditions and resulting critical loads

4. Launch, Recovery and Docking

Design and operating parameters governing weight
Critical design conditions and resulting critical design loads

5. Main Propulsion

Number
Material(s), types and properties
Types of construction
Expansion ratio
Port-to-throat ratio
% of nozzle submerged
Shape of nozzle
Motor mass fraction (total propellant weight divided by total motor weight)
Specific impulse - sea level
Specific impulse - vacuum
Characteristic exhaust velocity
Throat action time
Wet action time
Thrust coefficient (C_f)
Type of thrust vector control
Total impulse
Chamber pressure (P_c) - average
Chamber pressure (P_c) - maximum
Critical design conditions and resulting critical design loads

5. (cont.) Liquid Engines

Number
Material(s), types and properties
Type of propellant feed
Type of construction
Type of cooling - thrust chamber

Type of cooling - nozzle extension
Number of starts
Throttling ratio
Expansion ratio
Characteristic exhaust velocity
Mixture ratio
Ignition type
Specific impulse - sea level
Specific impulse - vacuum
Thrust coefficient
Design burn time
Thrust - sea level
Thrust - vacuum
Throat area
Exit area
Chamber pressure (P_c) - average
Chamber pressure (P_c) - maximum
Net positive suction head
Propellant flow rate - total and components
Design propellant temperature range
Critical design conditions and resulting critical design loads

5. (cont.) Thrust Vector Control

Type
Roll control thrust
Roll angular acceleration requirement
Maximum axial thrust misalignment
Longitudinal angular acceleration requirement
Normal force produced
Critical design conditions and resulting critical design loads

5. (cont.) Other Propulsion Subsystems

Design and operating parameters governing weight
Critical design conditions and resulting critical design loads

6-20 Orientation Control, Separation and Ullage Through Ballast

Design and operating parameters governing weight
Critical design conditions and resulting critical loads

21-27 Propellants and Service Items

Solid Propellant(s)

Composition and properties
Loading ratio - propellant volume to case volume
Web traction
Web thickness to propellant radius
Specific heat ratio
Storage/operating temperatures
Flame temperature
Characteristic exhaust velocity
Burning rate
Sliver percentage
Burning surface area

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APPENDIX D

PARAMETERS AND INVENTORY OF FLUIDS AND PROPELLANTS LOADED

D. 10. 0 GENERAL

This appendix is intended as a guide for the presentation of data required for establishing the parameters and inventory of fluids and propellants loaded (as discussed in par. 3.4.3.23).

D. 20. 0 FLUID PROPELLANTS - MAIN ENGINE

D. 20. 1 Parameters of Maximum Loadable Weight. - The following parameters are for the total load limited by the engine inflight mixture ratio (MR) requirement on effective burning propellants.

a. Engine number(s)

b. MR of engine(s) - (indicate actual or specified).

1. Acceptance MR at standard conditions.

2. Average inflight MR (indicate whether inclusive of consumption by gas generators, vernier engines, etc. and include reference to the current MR production analysis).

c. Tankage volumes at loading and at total gross weight conditions for each propellant (indicate actual or specified).

1. Gross tankage (total cavity above letdown valve).

2. Required ullage volume (include reference to the current ullage analysis).

3. Net maximum loadable volume (c1 - c2).

4. Volume below each discrete tank level which is significant in establishing the loaded or terminal weight of propellant.

d. Propellant bulk temperature - each propellant (highest assumed before ignition).

e. Ullage pressures at loading and tanking secure.

f. Propellant bulk density - each propellant (lowest assumed before ignition).

g. Maximum loadable weight vs average inflight MR - each propellant and total propellant.

D. 20. 2 Inventory of Load. - The following inventory is for each propellant and total (lb).

a. Total nominal propellant loaded.

b. Propellant expended before liftoff (total and details of bleed, leakage, venting, start, holdown, etc.).

c. Total propellant aboard at liftoff (a - b).

d. Propellant expended during flight (total and details of bleed leakage, venting, effective burning, shutdown, etc. for each major flight stage before separation of stage being reported).

e. Total propellant aboard at the end of each major flight stage.

f. Propellant aboard at separation of stage (total and details of trapped propellants and other system unusables), and reserve propellants (including propellant vapor retained).

D. 20. 3 Outage. - State any outage parameters, biases for outage if used, and indicate the mean and maximum probable outage. Account for these factors as used in the inventory. Include reference to the current outage prediction analysis.

D. 20. 4 Temperature and Density. - Present the variations of loading bias, mean outage, maximum outage, average inflight mixture ratio, and propellant density with temperatures in the range around that assumed for loading at the scheduled launch period. Include reference to the current temperature prediction analysis.

D. 30. 0 OTHER FLUID LOADS

For all other fluid loads (nonpropellant), the following parameters and inventory apply.

D. 30. 1 Parameters of Maximum Loadable Weight. - State the parameters defining maximum loadable weight of each fluid, including, as applicable, gross volumes, limiting and net volumes, pressures, temperatures, gas constants or density.

D. 30. 2 Inventory of Load. - State the inventory of each fluid as loaded, and details of utilization, trapped and reserve quantities during the major flight stages and at separation of the stage.

D. 40. 0 SOLID PROPELLANTS LOADED

D. 40. 1 Parameters of Maximum Loadable Weight. - Identify the total case volume, the total volume occupied by the maximum loadable propellant, and the remaining volumes unoccupied by propellant. State all parameters which directly limit and establish the maximum loadable propellant.

D. 40. 2 Inventory of Propellant Loaded. - Inventory the propellant weights assigned to each principal phase of propellant utilization during flight and total same to the total propellant loaded in each solid motor segment or case.

D. 40. 3 Sliverage. - State values of the parameters used to establish the sliverage and indicate the mean and maximum sliverage. Include reference to the current sliverage prediction analysis.

D. 40. 4 Thrust/Time Curve. - Provide the current thrust/time curve which matches the weight of the propellant loaded.

APPENDIX E

MASS PROPERTIES VERIFICATION PLAN

E.10.0 GENERAL

This appendix is a guide for preparing the mass properties verification plan discussed in par. 3.4.3.25. The following items shall be included.

a. Analytical Verification Items.

1. Items to be verified by analysis.

2. Analytical substantiation that test is not required for these items.

b. Experimental Verification Items.

1. Items to be verified by experiment.

2. Analytical substantiation that test is required for these items.

3. Estimated costs of proposed tests.

E.20.0 TEST PLAN

For each item to be tested, or for each block of tests, list the following:

a. Measurement objectives, including measurement to be performed and overall accuracy required.

b. Description of the test setup, including the location, measurement system proposed, equipment, fixtures, pertinent dimensions and reference datum locations, and environmental control provisions.

c. Measurement procedures, number of successful runs required, the use of average readings from a number of independent measurements, and the requirements for complete unloading, unbalance or shutdown of equipment between measurement readings.

d. Instrumentation calibration procedure and schedule.

e. Statement of overall uncertainty of the measurement system, with supporting analysis of the system showing calibration and systematic error analysis. The measurement system analysis shall indicate possible sources of random error, their method of estimation, and their possible effect on the precision of measurement, and shall show the method of combining different sources of error to obtain a value for overall uncertainty of the measurement process. The analysis also shall indicate the relationship of the uncertainty with the required accuracy.

f. Schedule, including equipment availability dates and test start and completion dates.

g. Test reporting plan, including submittal schedules, for reports containing the following minimum information:

1. Explanation of deviations from test plan.

2. Summary of data.

3. Evaluation of results.

4. Final conclusion of results.

5. Recommendations.

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APPENDIX F

CAPACITY AND LOADING INFORMATION FOR FLUIDS AND PROPELLANTS

F. 10. 0 GENERAL

This appendix lists the nominal information required to determine the parameters and procedures for pre- and post-flight evaluation of the loaded and unexpended fluid and propellant mass properties, as discussed in par. 3. 4. 3. 24.

F. 20. 0 FLUID SYSTEMS

For fluid systems, provide the following information:

a. Sketches of liquid propellant and fluid system, on which are noted such items as tank and plumbing volumes, loading volumes, sensors, ports, net positive suction head (NPSH), vortex levels, "letdown" valve levels and other significant discrete level locations.

b. Derivation of total usable and trapped volumes; presentation of nominal liquid volumes vs station levels for the various temperature, pressure and acceleration conditions expected.

c. Synoptic derivation and discussion of minimum ullage volumes, with reference to the basic ullage analysis documents.

d. Synoptic derivation and discussion of techniques for predicting the mean and maximum propellant outage, with reference to the basic outage prediction analysis.

e. Synoptic description and discussion of anticipated propellant temperature and rise rates at the launch site for each calender month, with reference to the basic temperature prediction program.

f. Synoptic descriptions of loading methods and procedures for control of the fluid weight as loaded, with reference to the basic methods and procedures documents.

g. Presentation of gas constants (R), propellant and liquid densities vs temperature, pressure and other environments expected.

h. Synoptic descriptions of test and flight instrumentation and procedures to determine the initial loadings and unexpended propellant and fluid weights from flight and static tests.

F. 30. 0 SOLID SYSTEMS

For solid systems, provide the following information:

a. Sketches of propellant system in plan, and significant cross-sections showing stations and dimensions for:

1. Grain configuration at initial loading and ignition.

2. Significant burntime grain configurations.

3. Typical terminal configurations of sliverage at end of web action time and end of action time.

4. Liner, insulation and bonding.

5. Igniter and thrust termination systems.

b. Volumetric data for:

1. Total case capacity.

2. Propellant, insulation and liner for conditions (a-1), (a-2), and (a-3) above.

c. Densities of propellants, insulation, liner and bonding materials.

d. Synoptic description of loading methods and procedures for control of the solid weight as loaded.

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